SEEPAGE LOSSES IN ISMAILIA CANAL

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Abstract

Ismailia Canal is one of the main important irrigation canals in Egypt. It was constructed in 1862. It transports fresh water from River Nile at north of Cairo to Ismailia, Port Said and Suez cities. In the final developing stage, the canal discharge is 433.56m^3/sec. One of the main problems that meet the Ministry of Irrigation and Water Resources is that about 90% from its total length passing through sandy soil. The quantity of seepage to the surrounding area varies from section to the other. MIWR developed different projects to minimize the seepage losses. It's planned to feed a new recliamated area in Sinai from Ismailia Canal. The seepage losses affect the water surface profiles, slopes, discharge, and water level. The main objectives of this research are evaluating seepage losses at different critical sections and comparing between different empirical, analytical and field measured results. The computed results which agree with measured results are discussed to deduce a formula available to compute seepage losses in the future.

Introduction

Figure (1) shows the layout of Ismailia Canal and table (1) shows the dimensions and characteristics of the different sections. It was firstly constructed between Zagazig and Ismailia to carry fresh water for water supply. The original canal dimensions are 2.4m deep and 18m wide. The total length of the canal is 128km. It has 4 regulators constructed along the total length. The first is a head regulator at km (0.00), the second at km. (13.8), the third at km. (28.150), and the fourth at km. (75.00). Through the last 20 years MIWR designed a program which consists of three stage to develop the canal. The first stage designed to pass a maximum discharge of 332.662m^3/sec, the second stage design to pass a maximum discharge of 346.76

m^3/sec and the final stage designed to pass 433.56 m^3/sec. The total area served in the final stage is 1082000 feddan and 5,000,000 m^3/day for drinking and industrial purposes. At now it is feeding five Irrigation Directorates by water requirements, Kalubia, Salhyia, Ismailia, Port Said, and Suez. We will study the effect of seepage losses on the efficiency of the canal. Its required to collect different data such as discharge at different sections, actual water cross-sections, types of boundary soil, water levels, and water tables.

Seepage Losses Equations

In this part we applied empirical formulae and analytical equations to evaluate seepage losses in different sections. Hunt, B. W. (1970) derived a linearized solution for the unsteady, free-surface seepage toward a ditch in an infinitely deep aquifer. Reddy, A. S. and Basu, U. (1976) studied seepage from trapezoidal canal in anisotropy soil. Binnie and Partners (1980) published a report of the field study of seepage losses in the canal for the three stages and reported that the maximum seepage losses occurred at a distance from km. 61.00 to km. 74.00. They found that the seepage loses in first stage is 1.9m^3/sec, second stage is 2.8m^3/sec and the third stage is 3.3 m^3/sec. Abdel-Halim, (1992) summarized different empirical seepage formulae and used them for evaluating the seepage losses in different Egyptian canals. There are different empirical and analytical equations used to evaluate the seepage losses. Kacimov, A. R. (1992) applied a complex-variable method and series of expansions to optimal-shape for designing a trapezoidal channel to compute seepage losses. Kattab, A. F. and Badwy, H. (1993) summarized different studies evaluating seepage losses in Ismailia Canal and reported that the maximum seepage losses occurred in distance from km.48.00 to km.70.50 which is 13.42% from the total discharge enter to the section. Also the minimum seepage losses occurred at distance from km.0.00 to km. 12.700 which can be nil. Mowafy, M. H. (1995) studied numerically and experimentally seepage problem in the case of unsteady flow.

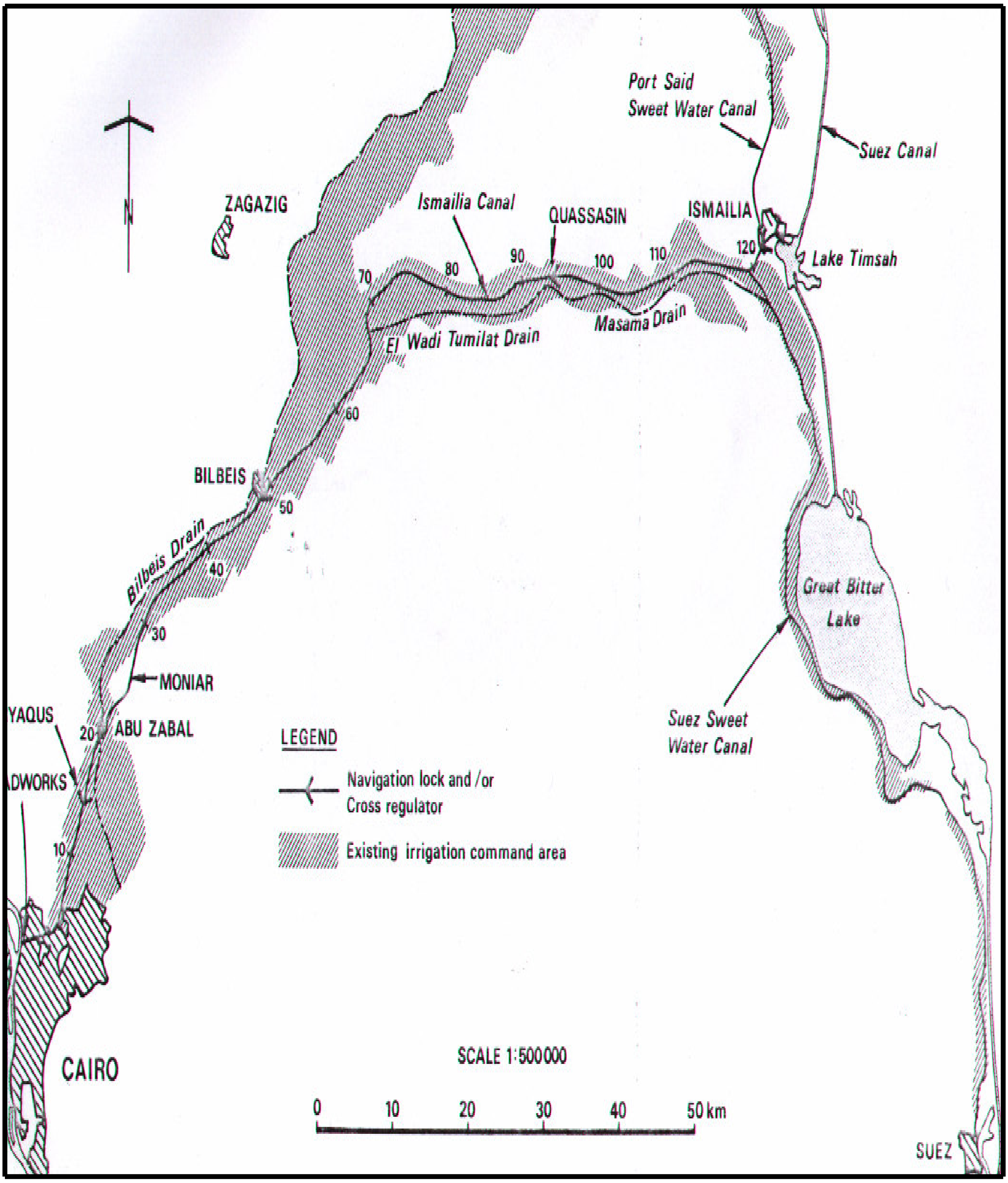

Figure 1. Layout of Ismialia Canal, Ref. (1).

Table (1) Dimensions and discharges of the study cases, (a) Stage No. 1

Sections	Bed Width(m)	bed level	Min. W.L	Max. W.L	Bed Slope (cm/km)	Qmax. (m^3/sec)	Qmin. (m^3/sec)
(0.0-10.50)	48	10.5	15.5	15.95	6.5	332.662	259.52
(10.50-28.00)	47	9.82	14.87	15.61	6.5	302.84	231.24
(28.00-49.00)	47	7.9	12.4	13.1	6.5	297.02	227.27
(49.00-67.00)	47	6.51	10.89	11.48	6.5	279.57	213.35
(67.00-71.00)	40	5.35	9.65	10.15	6.5	231.69	178.24
(71.00-75.00)	38	5.35	9.42	9.93	7	186.15	144.84
(75.00-93.00)	34	5.4	9	9.4	7	111.28	88.08
(93.00-97.00)	32	4.26	8.22	8.62	4.5	97.08	77.68
(97.00-112.00)	27	4.43	8.03	8.43	4	84.06	68.12
(112.00-123.00)	20	3.83	7.36	7.76	2	32.21	27.79
(123.00-128.00)	9	3.59	6.85	7.23	4	15.11	12.93

(b) Stage No. 2

Sections	Bed Width(m)	bed level	Min. W.L	Max. W.L	Bed Slope (cm/km)	Qmax. (m^3/sec)	Qmin. (m^3/sec)
(0.0-10.50)	51	10.5	15.5	15.95	6.5	346.76	269.72
(10.50-28.00)	49	9.82	14.87	15.61	6.5	316.15	241.11
(28.00-49.00)	49	7.9	12.4	13.1	6.5	310.32	236.82
(49.00-67.00)	49	6.51	10.89	11.48	6.5	293.36	222.73
(67.00-71.00)	46	5.35	9.65	10.15	7	249.75	191.48
(71.00-75.00)	40	5.35	9.42	9.93	7	204.22	158.09
(75.00-93.00)	40	5.4	9	9.4	4.5	129.34	101.33
(93.00-97.00)	36	4.26	8.22	8.62	4.5	115.15	90.92
(97.00-112.00)	32	4.43	8.03	8.43	4	102.13	81.37
(112.00-123.00)	32	3.83	7.36	7.76	4.5	41.59	34.66
(123.00-128.00)	9	3.59	6.85	7.23	4	27.95	24.67

(c) Stage No. 3

Sections	Bed Width(m)	bed level	Min. W.L	Max. W.L	Bed Slope (cm/km)	Qmax. (m^3/sec)	Qmin. (m^3/sec)
(0.0-10.50)	61	10.34	15.5	15.95	7	433.56	333.38
(10.50-28.00)	59	9.6	14.87	15.61	6.5	402.96	304.76
(28.00-49.00)	59	7.65	12.4	13.1	6.5	397.12	300.48
(49.00-67.00)	59	6.25	10.89	11.48	6.5	379.17	286.39
(67.00-71.00)	56	5.1	9.65	10.15	7	336.55	255.14
(71.00-75.00)	50	5	9.42	9.93	7	291.02	221.75
(75.00-93.00)	42	4.95	9	9.4	4.5	216.15	164.99
(93.00-97.00)	39	4.17	8.22	8.62	4.5	201.95	154.58
(97.00-112.00)	37	3.98	8.03	8.43	4.5	188.93	145.03
(112.00-123.00)	32	3.31	7.36	7.76	4.5	128.39	98.32
(123.00-128.00)	9	3.31	6.85	7.23	4.5	41.59	34.66

a- Empirical Formulae

1- Mortiz Formula (USSR)

$$S = 0.2 * C * (Q/V)^{0.5} \quad (1)$$

In which;

S: are the seepage losses in cubic foot per second per mile length of canal,

Q: is the discharge (ft^3/sec),

V: is the mean velocity (ft/sec), and

C: is a constant value depending on soil type taken as o.34 for clay and 2.2 for sand soil.

2- Molesworth and Yennidunia (Egypt)

$$S = C * L * P * R^{0.5} \quad (2)$$

In which;

S : the conveyance losses for a given canal length (m^3/sec),

L : the canal length in km.,

P : the wetted perimeter in m,

R : the hydraulic radius in m, and

C : the factor depends on soil types, for clay equal 0.0015 and for sand equal 0.003.

3- Indian Formula

$$S=C*a*d \quad (3)$$

In which;

S : the total seepage losses in ft^3/sec;

a : the area of wetted perimeter in million ft^2;

d : the depth in ft; and

C : factor depends on soil types and varies from 1.1 to 1.8.

4- Pakistanian Formula

$$S = 5.Q^{0.0652}.P.L/10^6 \quad (4)$$

In which;

S : seepage losses;

Q : the discharge in ft^3/sec,

P : the wetted perimeter of wetted section; and

L : length of channel in feet.

5- Hungarian Formula

$$S=1700*d_a*H*(b+H*S_o) \quad (5)$$

S : the seepage losses in m^3/day/per meter length of canal;

d_a : the effective size diameter of the grains of the soil;

H : the water depth;

b : the bottom width of canal; and

S_o : the bed slope.

Equation 5 used for calculating seepage losses for trapezoidal canal.

a- Analytical Equations

Vendernikov [6] developed two equations used to compute seepage losses from trapezoidal ditches or canals. The first one can be written as follows;

$$S = K(B+Ah) \quad (6)$$

In which;

S : the seepage rate in m^3/sec/m;

K : the hydraulic conductivity in m/sec;

h : the water depth in canal in m;

B : the top width in m;

A : Coefficient depends on soil type

Equation 6 used for deep drainage layer of finite depth otherwise the following equation is used;

$$S = K\frac{2H*n}{1-F(\beta,\phi)/K(\beta)} \quad (7)$$

The above equation can be written as follows;

$$\frac{S}{KH} = \frac{2*n}{1-F(\beta,\phi)/K(\beta)} \quad (8)$$

In which, n is cotα, α is the side slope angle and F(β/ϕ):the function of elliptic integration and can be determined from chart.

Farouk Mohamed [4], developed analytical equation to estimate seepage losses in earthen canal;

$$S = Q\left[\frac{e^{c_1 L} - 1}{e^{c_1 L}}\right] - L(C_2 - C_3)/(e^{c_1 L/2}) \tag{9}$$

In which;

S	: the seepage loss from canal in m^3/sec;
Q	: the flow discharge in m^3/sec;
$C_1 = (2e_2/v.d)$	: the seepage factor in m^{-1};
e_2	: the permeability in m/sec;
L	: length of canal in m;
V	: average velocity in m/sec;
d	: the water depth in m;
$C_2 = e_2 b$	: the seepage factor m^2/sec;
$C_3 = 2e_2 d((z^2+1)^{0.5} - z)$	: the seepage factor m^2/sec;
b	: the bottom width m; and
z	: the side slope.

Molesworth and Yennidunia [4] deduced analytical formulae to estimate seepage losses which are written as follows;

$$S = \alpha_s Q \tag{10}$$

In which;

S	: the seepage loss in $m^3/s/km$;
$\alpha_s = \dfrac{0.375 * 10^{-4}}{R^{1.166} .. i^{0.5}}$	: the seepage loss factors in clayey soil in m^{-1};
$\alpha_s = \dfrac{0.75 * 10^{-4}}{R^{1.166} .. i^{0.5}}$	: the seepage loss factor in sandy soil; and
R	: the hydraulic radius.
i	: the bed slope

Results Analysis

Tables 2 to 7 show that the results of the computed seepage losses for Ismillia canal at different critical sections at maximum and minimum flow for the current stage of development and the next stage. Tables 2 and 3 show the computed seepage losses for minimum and maximum flow stage No. 1. Tables 4 and 5 show the computed seepage losses for minimum and maximum flow in stage No. 2. The results indicated that the computed seepage losses increase as the dimensions of cross-section increase. Tables 6 and 7 show the results of the computed seepage losses for both minimum and maximum flow for the stage No. 3. All tables of results indicated that the maximum seepage losses occurred at section from Km. 49.00 to Km.71.00 and the minimum seepage losses occurred at the first section from Km. 0.00 to Km 10.50. Pakistanian and Indian formulae give results more the others emperical and analytical equations.

Comparison between Computed and Measured Seepage Losses

Kattab, A.F. and Badowy, H. A. discussed different studies which measured seepage losses of Ismillia canal. Table (8) shows a comparison between the previous studies, empirical results and analytical results. The table indicated that the results of Molesworth and Yennidunia's empirical formula and the results of the analytical equations are more agreement with the measured results. Table (9) indicated that the Molesworth and Yennidunia's formula from empirical methods and all analytical methods gave applicable results when compared with the different actual measurement. Kattab and Badowy divided the total length of the canal into five reaches and measured seepage losses in each reach. Table (9) shows a comparison between measured results, empirical formulae results, and analytical equations results for each reach. Table (10) shows the increased percentage of seepage losses due to the development of hydraulic cross-section in stage 2 and stage 2 relative to stage 1. The table indicated that the percentage of increases ranged between 7.1% and 46.43% in the two stages. Figures 2 to 4 show the comparison between computed seepage losses for minimum and maximum flow in the development stages. Figure 5 shows the comparison between computed and measured seepage losses in stage No. 1.

Table (2) The computed seepage losses by empirical and analytical formulae in the case of minimum flow, stage No. 1

Sections	Empirical Formulae(m^3/s/km)					Analytical Equations (m^3/s/m)		
	Mortiz Formula USSR	Molesworth and Yennidunia	Indian Formula	Pakstain Formula	Hungarian Formula	Vedernikov Method	Farouk Mohamed Equation	Molesworth and Yennidunia
(0.0-10.50)	0.025953	0.002177	0.126692	0.194169	0.033056	0.02593166	0.01125924	0.00860602
(10.50-28.00)	0.166125	0.007432	0.124279	0.190588	0.032691	0.02478014	0.00824265	0.0045995
(28.00-49.00)	0.147888	0.008294	0.082155	0.183643	0.041615	0.04208855	0.00938994	0.00827372
(49.00-67.00)	0.143914	0.006897	0.090785	0.181426	0.040505	0.04228039	0.00995828	0.00926676
(67.00-71.00)	0.120386	0.00131	0.335501	0.159498	0.033843	0.03804293	0.01811917	0.03742432
(71.00-75.00)	0.108246	0.001217	0.285532	0.149309	0.045647	0.05095744	0.01945709	0.03120287
(75.00-93.00)	0.085659	0.004559	0.044413	0.128851	0.036125	0.0458172	0.00486618	0.0048449
(93.00-97.00)	0.088814	0.001023	0.227942	0.126805	0.0374	0.04571968	0.01309572	0.02278226
(97.00-112.00)	0.068178	0.003153	0.04242	0.109006	0.019125	0.02776106	0.00429229	0.00651252
(112.00-123.00)	0.049698	0.001808	0.041346	0.085371	0.013891	0.02301541	0.00248379	0.00596373
(123.00-128.00)	0.020971	0.000439	0.035447	0.053512	0.005773	0.01513619	0.00215787	0.00725745

Table (3) The computed seepage losses by empirical and analytical formulae in the case of maximum flow, stage No. 1

Sections	Empirical Formulae(m^3/s/km)					Analytical Equations (m^3/s/m)		
	Mortiz Formula USSR	Molesworth and Yennidunia	Indian Formula	Pakstain Formula	Hungarian Formula	Vedernikov Method	Farouk Mohamed Equation	Molesworth and Yennidunia
(0.0-10.50)	0.02831133	0.002056	0.15063986	0.202982461	0.036031	0.035189	0.012552	0.010301
(10.50-28.00)	0.190717872	0.006777	0.16358384	0.203194207	0.037481	0.035548	0.009499	0.005414
(28.00-49.00)	0.171104932	0.007537	0.10983862	0.195591524	0.048088	0.060454	0.011118	0.00962
(49.00-67.00)	0.163470202	0.006347	0.117012154	0.1919686	0.045961	0.059472	0.01172	0.010952
(67.00-71.00)	0.134524353	0.001217	0.418495361	0.16837404	0.037778	0.053048	0.020136	0.044626
(71.00-75.00)	0.12194606	0.001124	0.361977644	0.157930702	0.051366	0.07165	0.022029	0.036557
(75.00-93.00)	0.095269432	0.004247	0.05488448	0.135501573	0.040139	0.063515	0.006064	0.005633
(93.00-97.00)	0.097886509	0.000957	0.276603602	0.133291325	0.041178	0.063384	0.014778	0.026489
(97.00-112.00)	0.075847138	0.002929	0.052434414	0.115097268	0.02125	0.03905	0.005046	0.007442
(112.00-123.00)	0.055421376	0.001671	0.051331701	0.090504823	0.015465	0.033052	0.002836	0.006444
(123.00-128.00)	0.023496351	0.0004	0.044344555	0.05795435	0.006446	0.022859	0.002407	0.008056

Table (4) The computed seepage losses by empirical and analytical formulae in the case of minimum flow, stage No. 2

Sections	Empirical Formulae(m^3/s/km)					Analytical Equations (m^3/s/m)		
	Mortiz Formula USSR	Molesworth and Yennidunia	Indian Formula	Pakstain Formula	Hungarian Formula	Vedernikov Method	Farouk Mohamed Equation	Molesworth and Yennidunia
(0.0-10.50)	0.02756144	0.00229	0.13454114	0.20295768	0.03512175	0.027046202	0.01181204	0.00875482
(10.50-28.00)	0.17313096	0.007691	0.12951992	0.19660053	0.03408188	0.025486532	0.00858117	0.00472384
(28.00-49.00)	0.15413085	0.008586	0.08562317	0.18962318	0.04338568	0.043330095	0.0097818	0.00850173
(49.00-67.00)	0.14999006	0.007142	0.09461774	0.18740005	0.04222872	0.043544761	0.01038546	0.00954241
(67.00-71.00)	0.13828234	0.001471	0.38537512	0.17647764	0.03891924	0.041898634	0.02012058	0.03688584
(71.00-75.00)	0.11389227	0.001269	0.30042574	0.15550702	0.04804895	0.052767009	0.02079632	0.03343253
(75.00-93.00)	0.10064147	0.005219	0.05218137	0.14560666	0.04250017	0.051315264	0.00560176	0.00657266
(93.00-97.00)	0.09980124	0.001126	0.25614131	0.13842148	0.04207521	0.049418684	0.01498256	0.02547263
(97.00-112.00)	0.08066425	0.003615	0.05018811	0.12306967	0.02266677	0.030989088	0.00511393	0.00726713
(112.00-123.00)	0.07908138	0.002619	0.06579074	0.11565111	0.02222604	0.030747346	0.00313641	0.00404183
(123.00-128.00)	0.02097123	0.000439	0.03544704	0.05581402	0.005773	0.015136189	0.00320287	0.01384697

Table (5) The computed seepage losses by empirical and analytical formulae in the case of maximum flow, stage No. 2

Sections	Empirical Formulae(m^3/s/km)					Analytical Equations (m^3/s/m)		
	Mortiz Formula USSR	Molesworth and Yennidunia	Indian Formula	Pakstain Formula	Hungarian Formula	Vedernikov Method	Farouk Mohamed Equation	Molesworth and Yennidunia
(0.0-10.50)	0.030064	0.002163	0.159966	0.211969	0.038283	0.036568	0.013191	0.010497
(10.50-28.00)	0.19875	0.007018	0.170474	0.209356	0.039076	0.036467	0.00989	0.005559
(28.00-49.00)	0.178319	0.007808	0.11447	0.201735	0.050135	0.062082	0.011596	0.009897
(49.00-67.00)	0.170365	0.006576	0.121948	0.198136	0.047917	0.061101	0.012252	0.011321
(67.00-71.00)	0.154502	0.001368	0.480643	0.185717	0.043445	0.057933	0.022442	0.043969
(71.00-75.00)	0.1283	0.001173	0.380838	0.164321	0.05407	0.073961	0.023557	0.039311
(75.00-93.00)	0.111917	0.004872	0.064475	0.15266	0.047222	0.070449	0.007054	0.007689
(93.00-97.00)	0.109984	0.001055	0.310788	0.145252	0.046325	0.068006	0.016988	0.029928
(97.00-112.00)	0.08972	0.003366	0.062025	0.129552	0.025185	0.043121	0.006074	0.008407
(112.00-123.00)	0.088134	0.002436	0.08163	0.121415	0.024745	0.042822	0.003732	0.004461
(123.00-128.00)	0.023496	0.0004	0.044345	0.060326	0.006446	0.022859	0.003485	0.014902

Table (6) The computed seepage losses by empirical and analytical formulae in the case of minimum flow, stage No. 3

Sections	Empirical Formulae(m^3/s/km)					Analytical Equations (m^3/s/m)		
	Mortiz Formula USSR	Molesworth and Yennidunia	Indian Formula	Pakstain Formula	Hungarian Formula	Vedernikov Method	Farouk Mohamed Equation	Molesworth and Yennidunia
(0.0-10.50)	0.03398242	0.00271376	0.17119343	0.235839	0.04335262	0.03107868	0.01424195	0.00957568
(10.50-28.00)	0.21729641	0.00920052	0.16964208	0.230257	0.0428251	0.02948661	0.01054034	0.00541085
(28.00-49.00)	0.19571143	0.01035515	0.11476223	0.223566	0.05514207	0.05051653	0.01217221	0.00971592
(49.00-67.00)	0.19114941	0.00864205	0.12774001	0.221501	0.05386509	0.0508624	0.01300295	0.01102561
(67.00-71.00)	0.17794954	0.00179567	0.52475521	0.210459	0.05013454	0.0492493	0.02525322	0.04400472
(71.00-75.00)	0.15443609	0.0016058	0.44240453	0.190566	0.0652261	0.06364272	0.02728846	0.04061632
(75.00-93.00)	0.11894647	0.00583407	0.06938132	0.16106	0.05020334	0.05541307	0.00878667	0.00954599
(93.00-97.00)	0.11051858	0.00121906	0.29009406	0.152373	0.04661741	0.05263315	0.02032248	0.04130656
(97.00-112.00)	0.10489999	0.0043776	0.07342563	0.146427	0.02948452	0.03577673	0.00803539	0.01053568
(112.00-123.00)	0.09085351	0.00285351	0.08671866	0.12981	0.02550015	0.03251243	0.0072605	0.01030818
(123.00-128.00)	0.02283021	0.00046723	0.04190364	0.060096	0.00626886	0.01598775	0.00389969	0.01764538

Table (7) The computed seepage losses by empirical and analytical formulae in the case of maximum flow, stage No. 3

Sections	Empirical Formulae(m^3/s/km)					Analytical Equations (m^3/s/m)		
	Mortiz Formula USSR	Molesworth and Yennidunia	Indian Formula	Pakstain Formula	Hungarian Formula	Vedernikov Method	Farouk Mohamed Equation	Molesworth and Yennidunia
(0.0-10.50)	0.036969	0.002571	0.202479	0.245657	0.047133	0.041549	0.015932954	0.011604
(10.50-28.00)	0.248068	0.008443	0.220859	0.243887	0.048839	0.041593	0.012160244	0.006418
(28.00-49.00)	0.224775	0.009479	0.151229	0.23655	0.063268	0.07129	0.01442049	0.011425
(49.00-67.00)	0.215635	0.008005	0.162426	0.233054	0.060714	0.070352	0.015296557	0.013174
(67.00-71.00)	0.197652	0.001679	0.646905	0.22057	0.055644	0.067141	0.028099757	0.053115
(71.00-75.00)	0.172402	0.001496	0.550856	0.200315	0.072752	0.087637	0.030926723	0.048677
(75.00-93.00)	0.130798	0.005483	0.08383	0.168799	0.055162	0.075485	0.010862741	0.011584
(93.00-97.00)	0.121538	0.001145	0.350526	0.159908	0.051222	0.072018	0.023109036	0.050073
(97.00-112.00)	0.115364	0.004108	0.088725	0.153809	0.032397	0.049112	0.009411877	0.012751
(112.00-123.00)	0.09993	0.002674	0.104803	0.136804	0.028019	0.045041	0.00849727	0.012549
(123.00-128.00)	0.025368	0.000429	0.051559	0.064976	0.006942	0.024053	0.004346098	0.020228

Table (8) Comparison between different results for computed and measured total seepage losses for stage No. 1

No.	Institute of Study or Applied Equation		Date	Seepage Losses (m^3/sec/km)
1	*Dr. Hammad Y. Hammad*		1958	0.426
2	*Institute of Hydraulics*		1973	0.399
3			1976	0.186
4			1977	0.200
5			1977	0.577
6			1980	0.106
7	*Netherlands Consulting Office*		1976	0.641
8	*Haskong Consulting Office*		1976	0.730
9	*Institute of Soil Mechanics*		1977	0.657
10	*Institute of Groundwater*		1977	0.092
11			1987	0.163
12	*Binnie and Partiners Consulting Office*		1987	0.087
13			1987	0.078
14	*Institute of Hydraulics-England*		1978	0.493
15	*Empirical Methods*	*Mortiz (USSR)*	Present Study	1.025
16		*Moleswortt andY.*		0.0383
17		*Indian*		1.4300
18		*Pakstain*		1.562
19		*Hungarian*		0.38118
20	*Analytical Equation*	*Venernikov*	Present Study	0.3815
21		*Farouk M.*		0.1033
22		*Molesworth and Y.*		0.1467

Table (9) Comparison between measured and computed seepage losses at different reaches for stage No. 1

No.	Institute of Study or Applied Equation		Seepage Losses at Different Reaches (m^3/sec/reach)				
			Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
14	Kattab and Badowy		0.0	4.5	11.43	1.43	1.13
1	Emperical Methods	Mortiz (USSR)	3.000	10.300	5.900	5.000	6.100
2		Moleswortt and Y.	0.0276	0.5189	0.1846	0.1501	0.1734
3		Indian	1.600	6.800	9.500	8.500	9.300
4		Pakstain	2.400	12.300	7.600	7.200	10.100
5		Hungarian	0.4000	2.4000	1.6000	2.100	2.000
6	Analytical Equation	Venernikov	0.3293	2.2066	1.8072	2.5161	3.014
7		Farouk M.	0.1429	0.5818	0.6317	0.6324	0.5948
8		Molesworth and Y.	0.1092	0.4248	1.0505	0.9372	1.1479

Table (10) The percentage of increase in seepage losses due to the development of the three stages

Name of Methods	Methods of Computation	% of increasing in minimum flow		% of increasing in maximum flow	
		Stages(1- 2	Stages(1- 3)	Stages(1- 2	Stages(1- 3)
Empirical Formulae	Mortiz, USSR	10.94868	38.28517	10.84253	37.1766
	Molesworth and Y.	8.242337	28.07572	8.429253	29.06758
	Indian	10.67461	47.02448	10.57406	45.14076
	Pakstain	7.998608	25.59103	7.749168	24.92984
	Hungarian	10.99792	37.96297	10.93012	36.96538
Analytical Equations	Vedernikov	7.902158	22.44347	7.101074	20.1133
	Farouk M.	9.86493	45.95491	10.21777	46.43249
	Molesworth and Y.	8.388194	42.90541	8.399346	46.6756

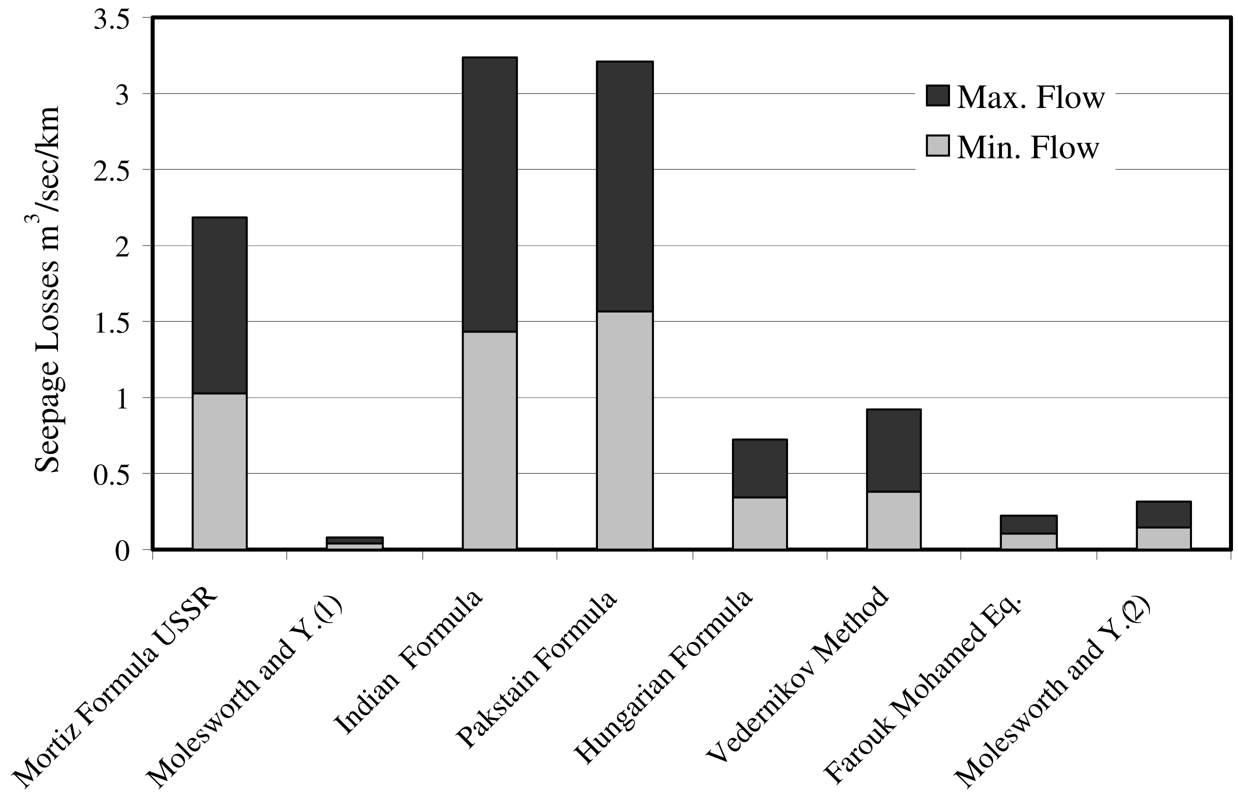

Figure (2) Shows comparison between different emperical and analytical equations for computed total seepage losses in stage No. 1

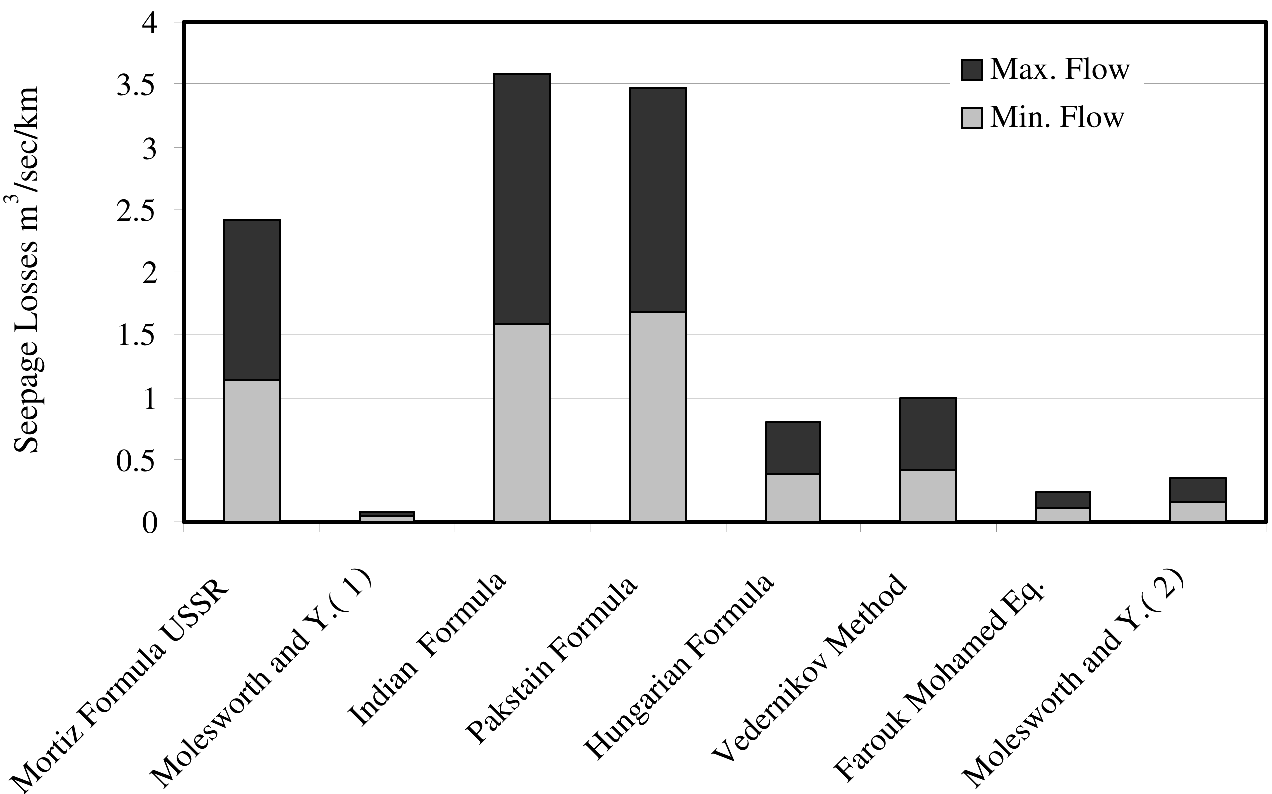

Figure (3) Shows comparison between different emperical and analytical equations for computed total seepage losses in stage No. 2

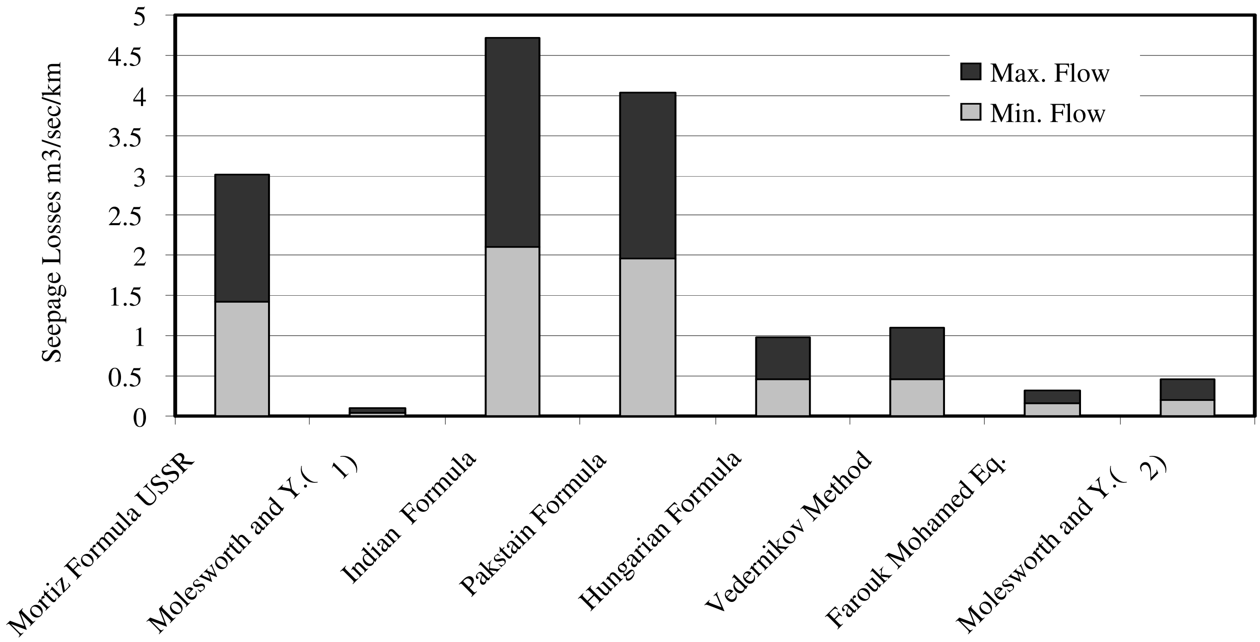

Figure (4) Show comparison between different emperical and analytical equations for computed total seepage losses in stage No. 3

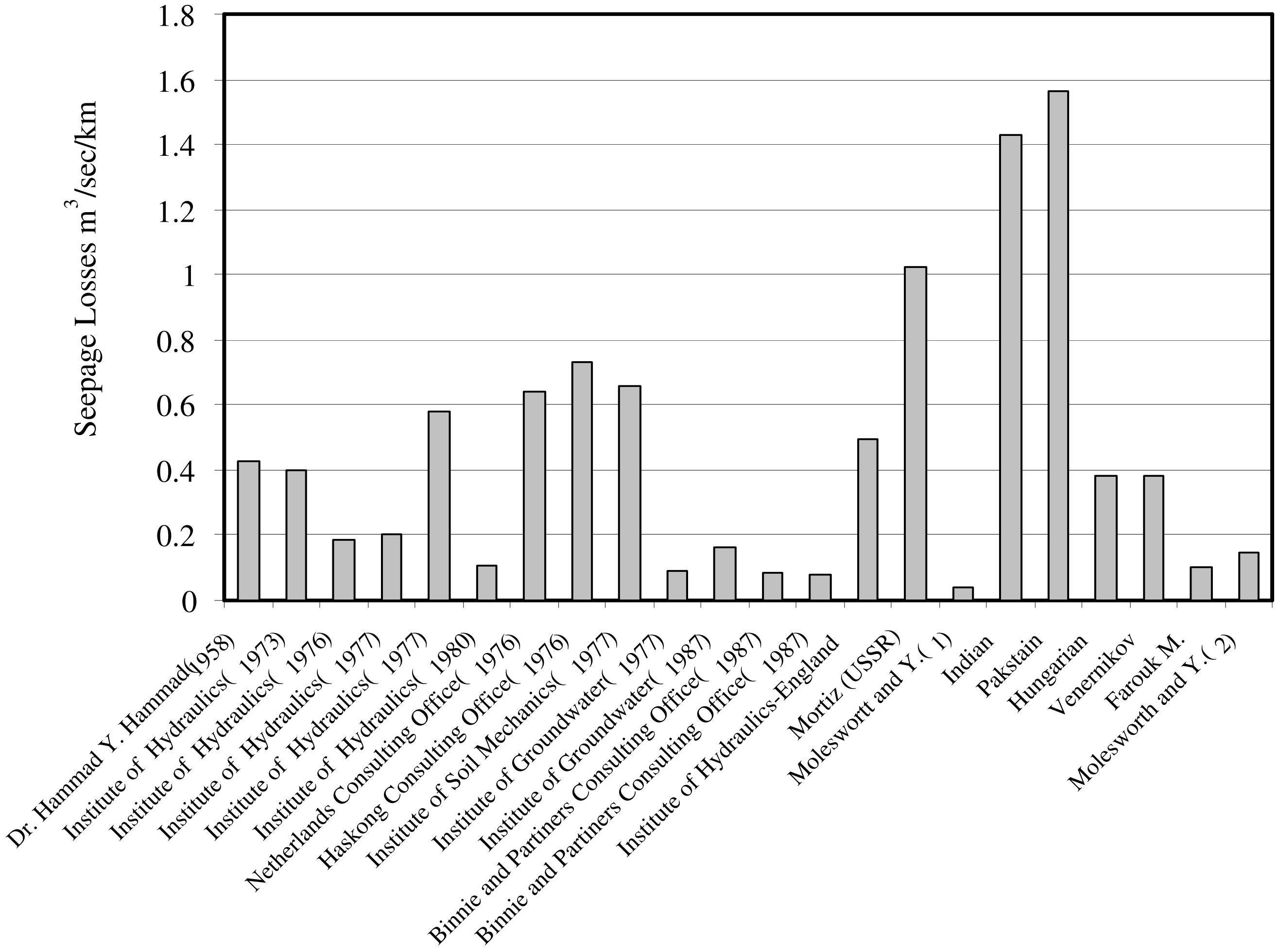

Figure (5) Show comparison between measured and compute total seepage losses in stage No. 1

Conclusions

Seepage losses of Ismailia Canal were computed by empirical formulae and analytical equations at different sections along the total length of the canal. The main conclusions can be summarized as follows;

1. The minimum seepage losses occurred at section No. 1 from Km. (0.00) to Km. (10.05) and the maximum seepage losses occurred at section No.4. from Km.(49.00) to Km.(67.00).
2. The computed seepage losses in stage No. 2 & 3 of development indicated that the seepage losses increase by 7% to 47.0% due to the increase of the discharge and cross-section dimensions when compared with the first stage.
3. The results of computed seepage losses by empirical formulae of Molesworth and Yennidunia and Hungarian, and by all analytical equations give good results when compared with different field measured results.
4. The maximum expected seepage losses in stage No. 2 is 0.5753m^3/sec/km and maximum seepage losses in stage No. 3 is 0.645 m^3/sec/km ,which represent about 20% from the total discharge.
5. We advise using all analytical equations and the empirical formula of Molesworth and Yennidunia for computing seepage losses in all canals of Egypt which are similar to Ismailia Canal.

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Notations

Min. : minimum;
Max. : maximum;
Qmax : maximum discharge;
Qmin : minimum discharge;
W.L. : water level; and
Y. : Yennidunia